Updated 2019-12-03 to include IGRF12 SV model comparison

1.1. IGRF12 Candidate SV models – Retrospective evaluation

Our aim here is to compare the IGRF-12 candidate secular variation models (2014 Fall) with a global set of geomagnetic observatory data. Additionally we evaluate the official IGRF12 SV model, mean and median of all candidate models. We use hourly mean database of geomagnetic observatory data compiled by the British Geological Survey for years 2006-2019 (update of September 2019). We limit the observatories to those located below geomagnetic latitudes of |55|. Observatories with baseline errors, large data gaps were omitted from the analysis. A total of 42 geomagnetic observatories, distributed across the world, were available for the analysis (Figure 1). Most of the observatories have data coverage up to June 15, 2019 (range March 24, 2019 to August 29, 2019). We select data for geomagnetically quiet condition (ap <= 10) and limit the analysis to 0-5 LT to reduce the influence of disturbance signals. We fit cubic splines with knots separated by 1 year separately to X, Y and Z components in a least-square sense. Secular variation at an observatory was determined by subtracting the spline value at the beginning and end of a year centered on the SV year of the model. The spline model is linearly extrapolated to 2020.0 using the slope at the last knot. We then find the global mean and root-mean-square (RMS) of the differences between model and prediction. Examples of observatory data analysis (Figures 2-6). The RMS errors were calculated after the global means were removed from all the differences (Table 1 & 2).

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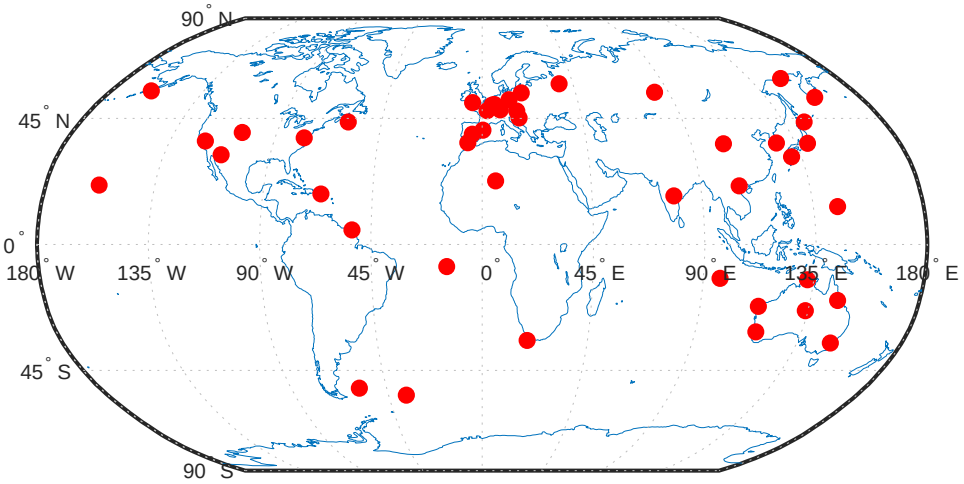

Figure 1. Observatories used in the model validation

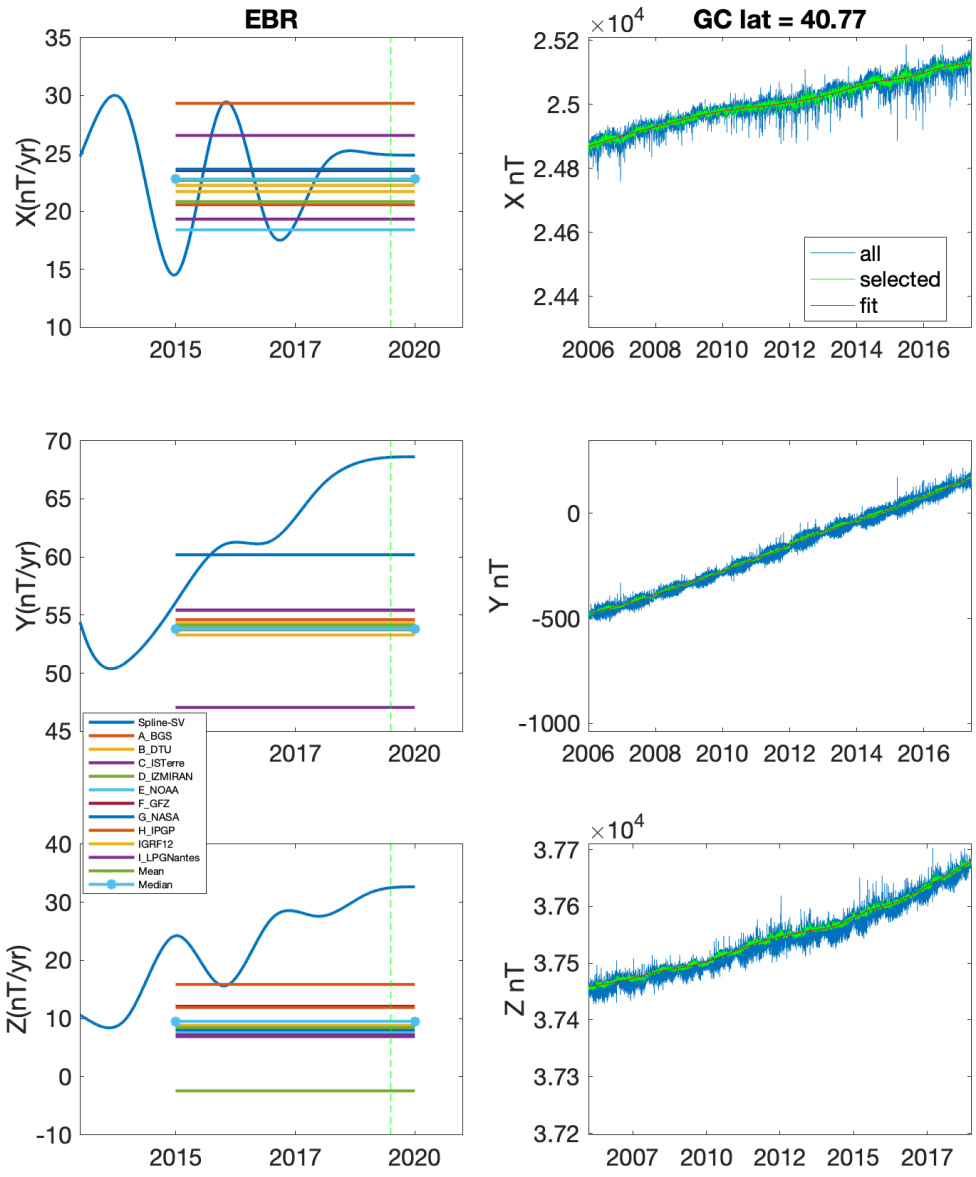

Figure 2. An example of SV determination at station EBR. The blue lines on the left panels represent the spline model of the SV obtained from the observatory data. The green vertical lines represent the last annual knot (= last data) for the observatory. Right panels show the spline fits to the measured data.

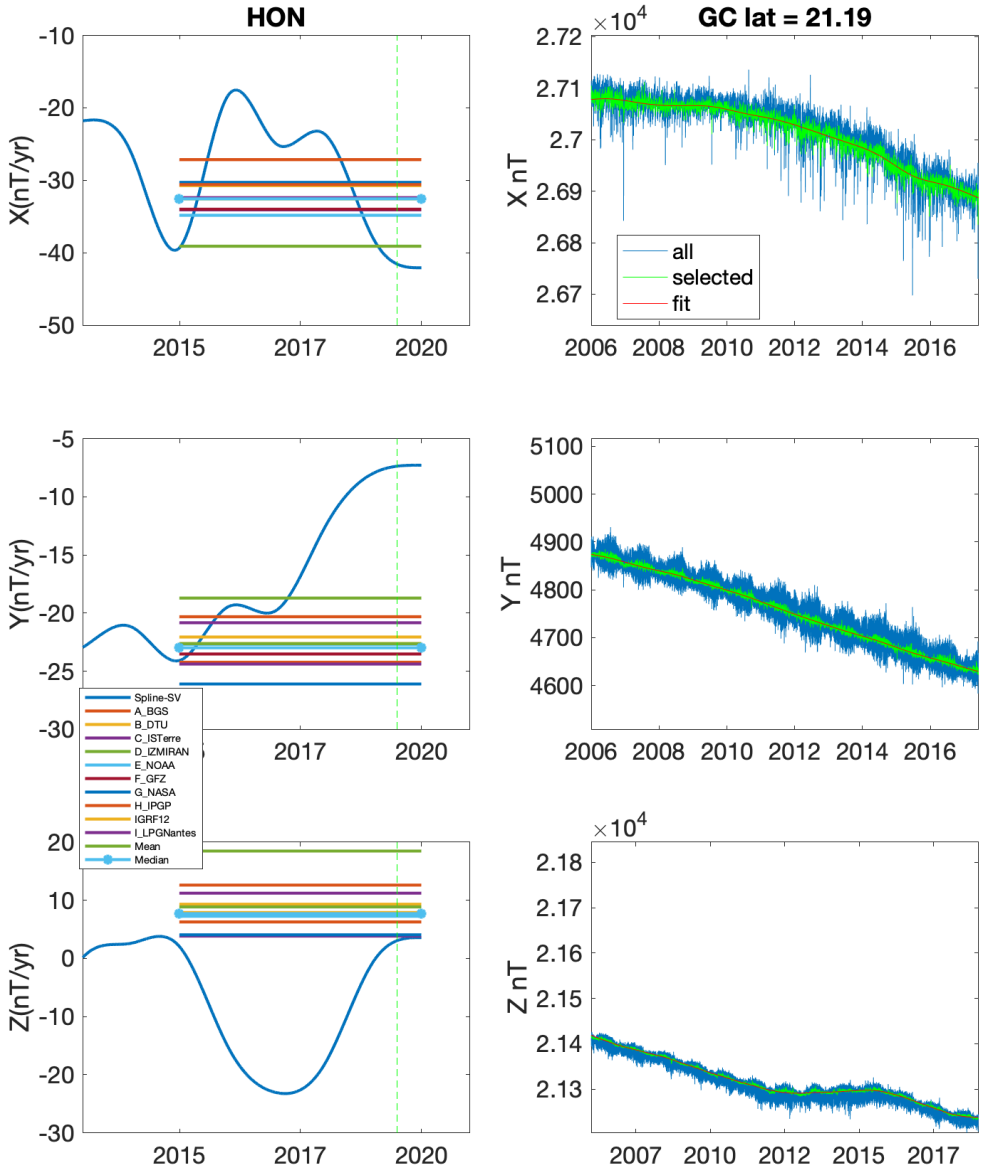

Figure 3. An example of SV determination at station HON. The blue lines on the left panels represent the spline model of the SV obtained from the observatory data. The green vertical lines represent the last annual knot (= last data) for the observatory. Right panels show the spline fits to the measured data.

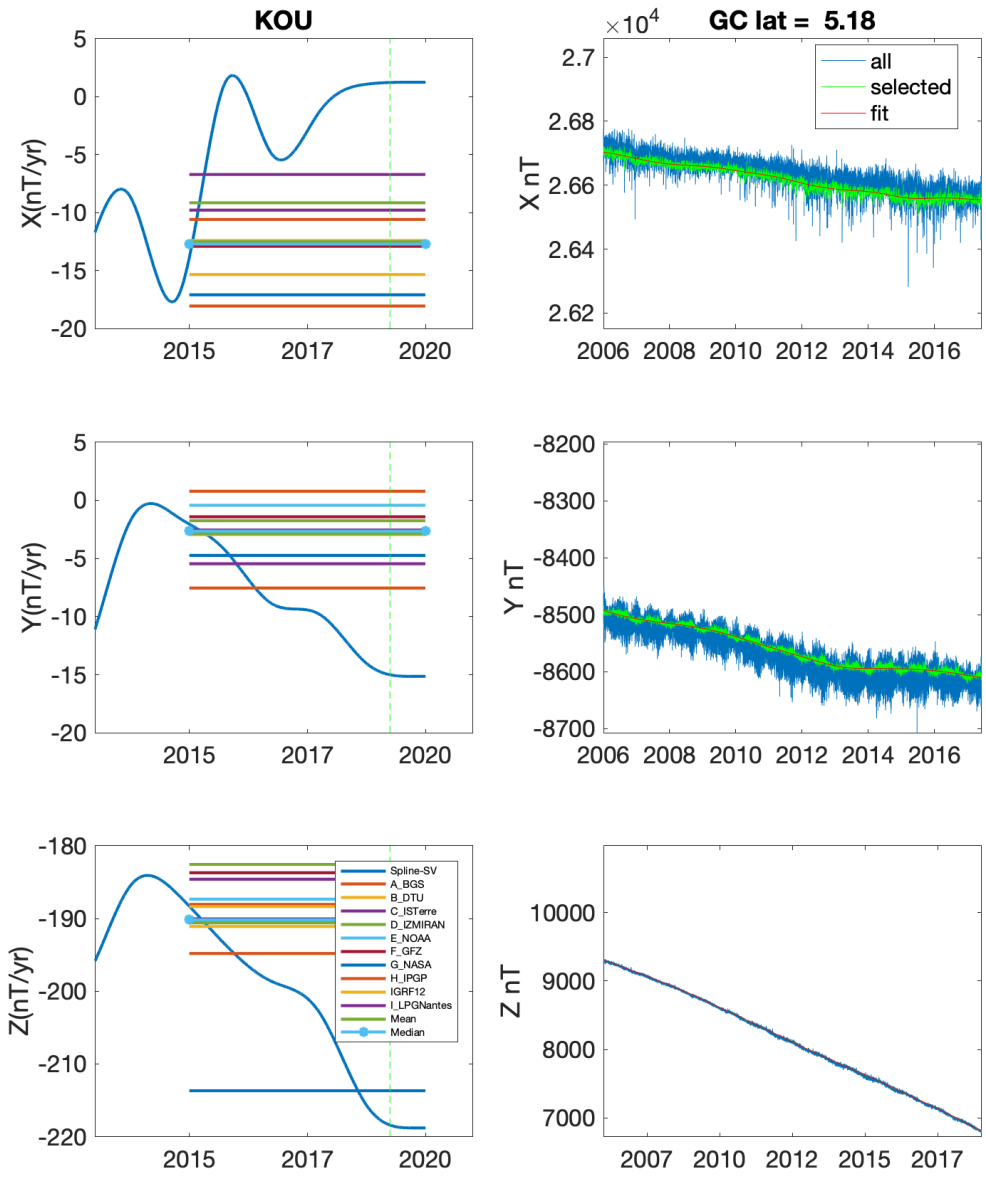

Figure 4. An example of SV determination at station KOU. The blue lines on the left panels represent the spline model of the SV obtained from the observatory data. The green vertical lines represent the last annual knot (= last data) for the observatory. Right panels show the spline fits to the measured data.

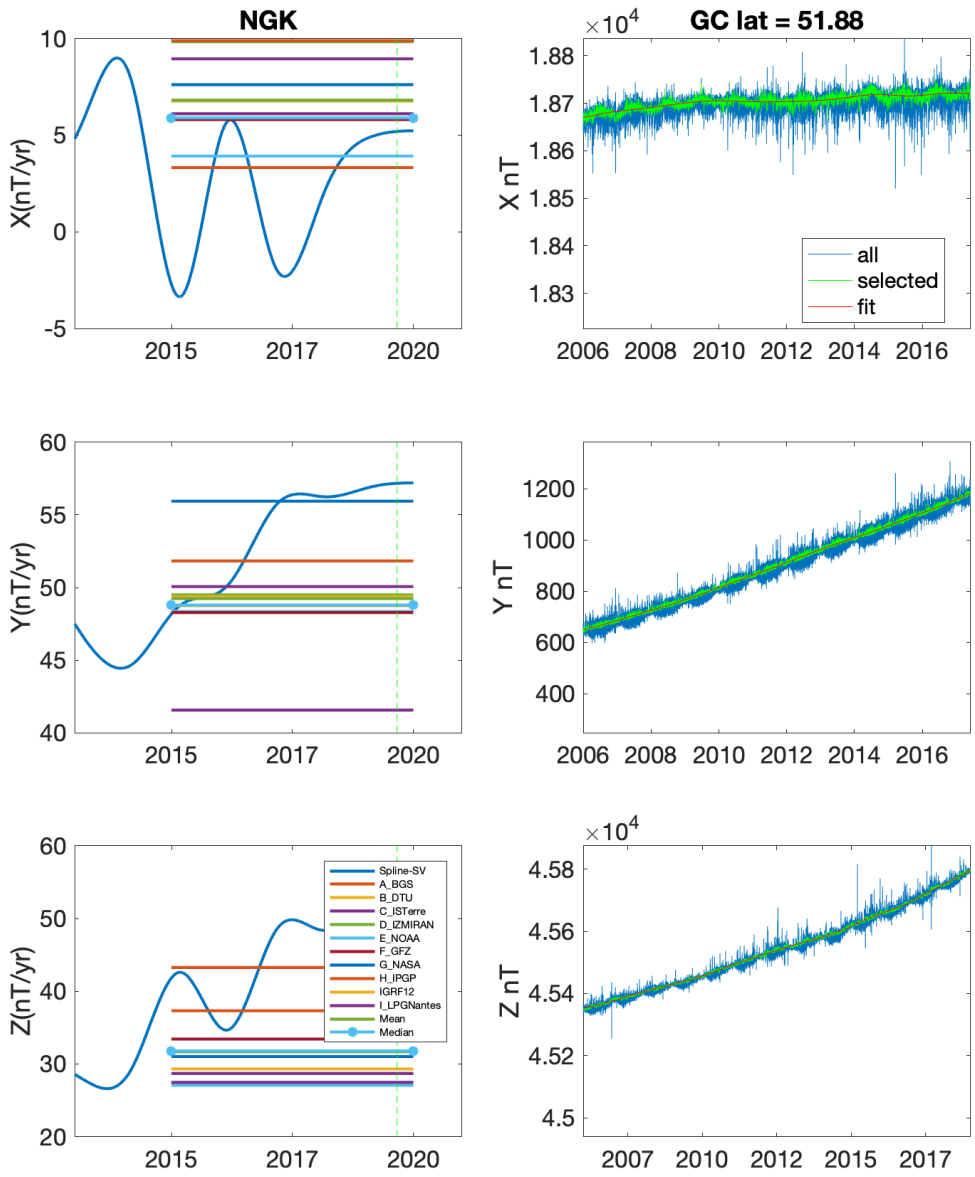

Figure 5. An example of SV determination at station NGK. The blue lines on the left panels represent the spline model of the SV obtained from the observatory data. The green vertical lines represent the last annual knot (= last data) for the observatory. Right panels show the spline fits to the measured data.

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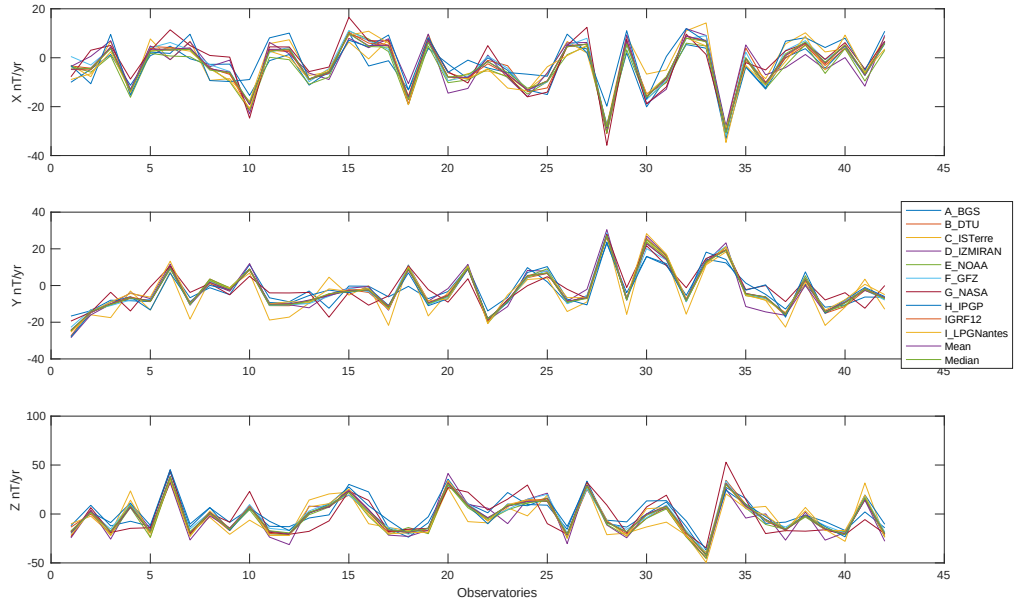

Figure 6. Residuals between IGRF12 SV models and SV observations at 2015.0 for 42 observatories. No outliers are present.

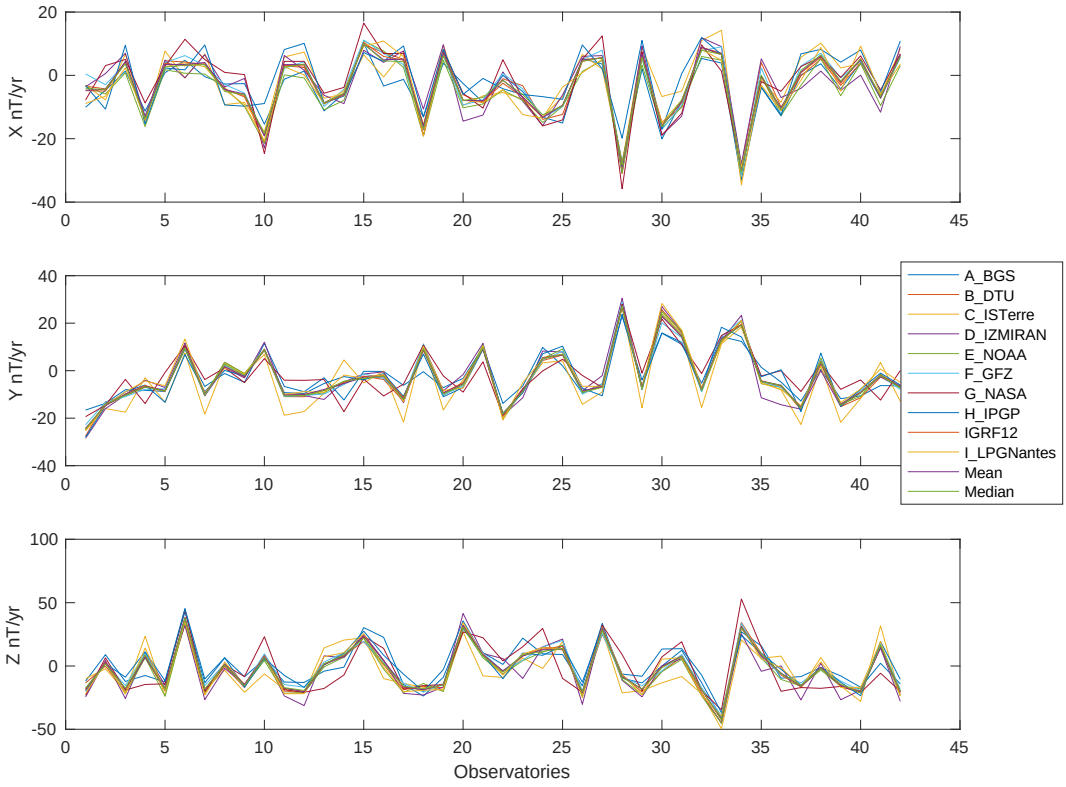

Figure 7. Residuals between IGRF12 SV models and SV observations at 2017.5 for 42 observatories. No outliers are present.

Model	SV Year	X RMS (nT/Yr)	Y RMS (nT/yr)	Z RMS (nT/yr)
A_BGS_sv.txt	2015	4.48	4.32	12.33
B_DTU_sv.txt	2015	3.69	3.31	9.64
C_ISTerre_sv.txt	2015	3.85	5.49	12.51
D_IZMIRAN_sv.txt	2015	4.88	4.72	12.24
E_NOAA_sv.txt	2015	3.36	3.35	10.23
F_GFZ_sv.txt	2015	3.77	3.09	8.19
G_NASA_sv.txt	2015	6	5.19	15.06
H_IPGP_sv.txt	2015	5.09	4.11	8.86
I_LPGNantes_sv.txt	2015	3.78	3.33	10.34
Mean_sv.txt	2015	3.37	2.95	9.59
Median_sv.txt	2015	3.25	3.03	9.19
IGRF 12	2015	3.28	3.01	9.58

Table 1. The root-mean-square (zero-mean) of the differences between observed and predicted secular variation at observatories.

Model	SV Year	X mean (nT/Yr)	Y mean (nT/yr)	Z mean (nT/yr)
A_BGS_sv.txt	2015	5.66	-0.28	-1.27
B_DTU_sv.txt	2015	6.98	-0.79	-4.68
C_ISTerre_sv.txt	2015	7.75	-2.82	-5.82
D_IZMIRAN_sv.txt	2015	7.04	-0.45	-5.91
E_NOAA_sv.txt	2015	5.02	-0.5	-5.66
F_GFZ_sv.txt	2015	7.39	-0.63	-2.8
G_NASA_sv.txt	2015	7.91	0.5	-3.2
H_IPGP_sv.txt	2015	8.86	-0.7	-0.17
I_LPGNantes_sv.txt	2015	6.33	0.11	-3.77
Mean_sv.txt	2015	6.99	-0.62	-3.7
Median_sv.txt	2015	6.89	-0.65	-3.79
IGRF 12	2015	6.88	-0.49	-3.58

Table 2. The mean error of the differences between observed and predicted secular variation at observatories.

Model	SV Year	X RMS (nT/Yr)	Y RMS (nT/yr)	Z RMS (nT/yr)
A_BGS_sv.txt	2017.5	8.95	9.13	17.16
B_DTU_sv.txt	2017.5	9.85	11.67	17.78
C_ISTerre_sv.txt	2017.5	10.42	13.18	19.47
D_IZMIRAN_sv.txt	2017.5	10.49	12.63	20.4
E_NOAA_sv.txt	2017.5	9.61	11.74	18.21
F_GFZ_sv.txt	2017.5	10	11.25	17.1
G_NASA_sv.txt	2017.5	11.38	10.21	20.91
H_IPGP_sv.txt	2017.5	9.8	10.77	16.84
I_LPGNantes_sv.txt	2017.5	9.72	11.6	18.87
Mean_sv.txt	2017.5	9.64	10.16	17.64
Median_sv.txt	2017.5	9.43	11.24	17.34
IGRF 12	2017.5	9.55	11.11	17.77

Table 3. The root-mean-square (zero-mean) of the differences between observed and predicted secular variation at observatories.

Model	SV Year	X mean (nT/Yr)	Y mean (nT/yr)	Z mean (nT/yr)
A_BGS_sv.txt	2017.5	-4.48	-2.22	-0.16
B_DTU_sv.txt	2017.5	-3.16	-2.73	-3.56
C_ISTerre_sv.txt	2017.5	-2.39	-4.77	-4.71
D_IZMIRAN_sv.txt	2017.5	-3.1	-2.4	-4.8
E_NOAA_sv.txt	2017.5	-5.12	-2.45	-4.55
F_GFZ_sv.txt	2017.5	-2.75	-2.58	-1.69
G_NASA_sv.txt	2017.5	-2.23	-1.44	-2.09
H_IPGP_sv.txt	2017.5	-1.28	-2.65	0.94
I_LPGNantes_sv.txt	2017.5	-3.81	-1.83	-2.66
Mean_sv.txt	2017.5	-3.15	-2.56	-2.59
Median_sv.txt	2017.5	-3.25	-2.6	-2.68
IGRF 12	2017.5	-3.26	-2.43	-2.47

Table 4. The mean error of the differences between observed and predicted secular variation at observatories.

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